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ABSTRACT

Recently computers have been of growing importance in teaching physics. This paper provides physics teachers and administrators with a basis for institutional planning for computers within physics courses. Different computer uses are discussed including instruction, computation, lecture demonstration and simulation. Different available computer terminals including "batch" and time-sharing systems are briefly described, and estimates are given for levels of use in courses. Final sections deal with auxiliary equipment, language and maintenance. (RB)

COMPUTER NEEDS FOR TEACHING PHYSICS

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With assistance from the participants in the Cooperative Physics Instruction Program, Lawrence Hall of Science, Berkeley, and Northern California Community Colleges, and attendees of the COMUSE Conference at Illinois Institute of Technology.

Recently computers have been of growing importance in teaching physics. While few schools now use computers within physics classes, the number will soon increase rapidly. The purpose of this document is to provide physics teachers, departmental chairmen, and administrators with a basis for institutional planning for computers within physics courses. Plans for computer usage in learning will presumably include many areas, but here our concern is with physics.

Reasons for Computer Use in Physics

Although computers will serve, in future, more in teaching in all disciplines, they are specially relevant to physics education for a number of reasons. First, the computer is an important tool in contemporary physical research, so physics students should certainly learn about computers just as they learn about other

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standard pieces of laboratory equipment: as students encounter oscillographs in our undergraduate curriculum, they should also encounter computers. If they do not see computers early in their careers, perhaps in the freshman or sophomore year, they are likely to be handicapped.

Colleges and Universities should also note that students are more likely to use computers both before and after college. While until recently few high school students had computer experience, the trend is now for more and more students to arrive in college with often extensive computer knowledge. These students expect to be able to extend their experiences. Likewise the graduates of two year colleges may go to universities where students will have had experience with computers in lower division courses, and these students will be handicapped without such experience. The university or four year college graduate will encounter a similar situation in graduate school.

The computer is also a very effective and powerful teaching device within physics classes, as is shown by recent experiences at Dartmouth College, Florida State University, State University of New York at Stony Brook, and the University of California, Irvine. The problem-oriented logical structure of physics suggests many natural ways computers can be effectively used in the teaching process.

Types of Use

We are only briefly reviewing types of computer use in physics teaching, giving references for expansion of these items. First,

computers can engage students in dialogs which approximate contact with a live teacher. The computer outputs information or phrases a problem. The student responds in free form and, depending upon the computer's analysis of the response, it either supplies additional information, remedial assistance, or proceeds to the next problem. The interaction between students and computer is dynamic, with the conversation much as if an instructor were typing the messages the students see.

The second use of computers within physics courses can be described as computational. The student uses the computer as a computer, writing programs in standard programming languages that help him learn physics in new and often exciting ways. With the computational use of the computer, in certain areas of physics, it is practical to present material sooner, thus advancing the student rapidly to the more interesting contemporary areas of physics.

A third use of computers in teaching physics is in lecture demonstrations. The computer enables the teacher to illustrate and explain phenomena difficult to understand with only lectures, demonstrations, and film.

A fourth method for using computers in physics classes is simulation, where the computer behaves like a physical system. Thus students can perform a laboratory experiment for which equipment is not available or possible.

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A fifth use is to employ the computer as a device to draw students into the details of a problem. Before students can successfully solve a problem on the computer they must understand the problem completely. The computer is thus a valuable pedagogical device to motivate true understanding of a problem.

Types of Computers in Education

Computers of different types have been and will continue to be used in teaching. The following break-down is helpful in understanding the range of possibilities.

It is convenient to have a scale for comparing these machines with regard to student usage; we will use the individual student terminal or or station as such a scale. Such a terminal, usually a typewriter-like device such as a teletype, can be used by only a small number of students at one time.

The first possibility, already present in many high schools and some smaller colleges, is the minimal small computer, now purchasable for well under $10,000. Such a computer is equipped with only teletype input and output facilities, and has limited internal storage. It is sufficient for many of the computational uses within physics teaching. Because of this minimal storage and facility for input and output, there may be more difficulty in teaching students to use such a computer. On the other hand, because it is a relatively inexpensive device, students can become intimately acquainted with the small computer, using time for perhaps inefficient projects. The small stand-alone computer is equivalent

to one terminal, as one student ties up the whole machine. The small computer is continuing to decrease in price dramatically, so cannot be ignored by the educational planner.

A second type of computer system is the small stand-alone computer with card reader, and, perhaps, with a magnetic disk system for storing user and system programs. Typical machines cost from $20,000 to $60,000. If a machine of this kind is used in a free fashion, with students themselves operating the machine and with card punches in the same room, it is equivalent to perhaps four or five single timesharing terminals, although this number is not precise. In addition to the increase numbers of students who can use the machine, it is likely to have more memory, including the disk memory, so has the ability to store programs which can be accessed by the students, a facility much less available with the minimal computer.

A third type is the medium or large batch computer system. "Batch" means that jobs to the computer are in decks or punched cards or paper tape. This is the common computer facility, both in business and research applications. It is difficult to give a comparison to a terminal system, as we have been doing above; relative student usage dependent on the size of the computer and, even more important, the policies with regard to how the system is used. If the system can be used <u>directly</u> by students having full control of the machine, a medium scale computer with many card punches in the same room for for student use might be viewed as equivalent to at least ten time-sharing terminals, for computational uses. However, a system where

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the student is shielded away from the machine by a hierarchy of computer facility operators, programmers, etc., would not provide this much educational service. The "turn-around" time, the time between the moment when the job is ready to the moment when the output is available, becomes particularly important. If the student puts his deck of cards in a slot, and receives the printout three days later, interactive student use is very much inhibited, although even in this environment <u>some</u> educational goals can be achieved. Computer center policy can have a large role in determining how effectively the computer can be in the classroom; many computer centers are <u>not</u> run in ways conducive to educational needs.

The fourth kind is a small timesharing system. For between $20,000 to $150,000 one can buy from a number of vendors timesharing systems supporting from two to thirty-two terminals. While these systems do <u>not</u> have the full capability of the larger systems described next they cover much of the range necessary for teaching physics. These systems are a relatively new development; they can provide for many schools a relatively inexpensive terminal access. As with larger timesharing systems, the facility could be shared by a number of schools; terminals can be a considerable distance from the central computer, and can be connected to it via phonelines.

The full-scale timesharing system can have many more terminals and many more resources available for the student, including editing facilities for storing and maintaining large files. Such a system,

with terminals spread over the campus, affords maximum usability for students, provided it is available much of the day (perhaps even 24 hours).

Finally an "outside" timesharing system, a commercial or university system located elsewhere, can be reached via telephone. In the past costs have often precluded extensive use of commercial facilities, but it may be practical to call nearby universities, and recently less expensive commercial facilities have become available. Here the cost of the terminals is a function of the desired and required services. Educational discounts and other special arrangements are often possible. A very good survey of time sharing costs is in a present issue of Physics Today.

In all of the computer systems described above many financial options are available, including purchase, lease, and lease-purchase. A system too expensive to purchase outright may be feasible if leased over a long period with option to purchase applying a percentage of the lease payment towards the purchase price.

Estimates and Requirements in Physics Classes

In this section we estimate what is required to use computers effectively in physics classes, in the near future. The estimates are in computer terminal hours per student per week; this can be translated, using the previous section, into various types on computers.

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We distinguish two types of physics courses, the four unit high level lecture-laboratory course, and the three or four unit entry level course. In each case we state in the table a heavy use and a light use figure. Individual areas of courses will probably fall within this range with different semesters or quarters having usage depending on the subject matter being covered. These figures are to be considered as general guides rather than fixed values.

	HEAVY	LIGHT
High Level	1	.25
Entry Level	.5	.1

Suggested computer terminal usage for physics courses, in terminal hours per student per week.

For example in a high level course with 200 students, one would expect to need 200 terminal hours per week if the use were very heavy; these figures represent actual use in one university at present.

We can translate terminal hours into the number of terminals if one knows how many hours per week the machine is available. Thus if the computer runs from 8:00 in the morning until 10:00 at night, 14 hours a day, for 5 days a week, a terminal can be used 70 hours in a week. In the above example that would mean that one would need 200 divided by 70, or about 3 terminals to support the course. However it is unrealistic to assume 100% usage, and the maintenance and repair of terminals must also be taken into consideration.

Types of Auxiliary Equipment

A section above describes computer facilities. Computer usage within classes is also affected by the peripheral equipment. Hence a brief guide to such equipment and its effect on teaching is desirable.

Perhaps the most useful single piece of auxiliary equipment for teaching purposes is a plotting device. Plotters are relatively uncommon as of this writing. Graphs and pictures can be drawn on paper or on the face of a cathode ray tube; recently a dramatic decline in costs has occurred. Th pedagogical usefulness of graphs and curves can hadly be over-estimated, so it seems reasonable that graphic devices will play an important role in future computing.

A limitation of a small computer is the slowness of getting information, programs, and data into the computer, and getting data out. Units which provide faster input and output are expensive compared with a minimal computer system. However, they increase student through-put, allowing more students to use the system. The fast printer is much quicker than a teletype or typewriter. Likewise a fast tape reader, or standard or mark sense card reader, provide quicker input. Manufacturers have a range of such devices; so it is difficult to give detailed advice without knowing the particular situation. But the more rapid the input/output device the more likely it is that more students can effectively use the computer.

A disk also makes the computer more effective for student use, if it comes with programming support. Programs can be stored in a

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library, essential for most dialogue-type usage, but also desirable for programs often used by the students such as data analysis programs for laboratory.

Languages

Communication with the computer demands a "language" for describing calculations. A minimum requirement for a computer for physics classes is a high-level formula-oriented language. It is desirable to use languages which can be found on many machines. Five such languages are in common use in this country: APL, PL/I, JOSS, BASIC, and FORTRAN. All of these languages can be used in physics classes in computational work, although different instructors strongly prefer one to another. For a timesharing system we need to distinguish between languages used by students from terminals, and languages which cannot be used directly from terminals. We require that the computer have one of these languages available, but any computer is very likely to have at least one; so in practice this requirement in minimal.

Expandability

The computer field is dynamic, and the use of computers in teaching is expanding rapidly. So any system should allow for growth, going into a larger system as needs increase. Programs which are developed for one machine will not necessarily run on another machine, so a large computer of the same type may be desirable.

One approach is to request bids on a system specified in two levels, one to meet current teaching needs, and the other to meet needs expected in three years, with the understanding that no commitments will be made for the later period until that time arrives. The two machines bid should accept the same programs.

Maintenance

Computer maintenance is, as with all expensive equipment, a serious problem which must be taken into account in selecting the machine. Local maintenance is almost essential for effecient use of computers in educational situations; the class cannot wait for weeks while the computer is being repaired.

Hence, if a repairman comes from great distances, and so cannot arrive almost immediately after the trouble accurs, the educational effectiveness of the system decreases markedly. Nothing discourages students more than a computer system which has constant problems.

Various maintenance arrangements with the manufacturers are possible. Perhaps the most desirable is the yearly contract, where the manufacturer agrees for a fixed price to maintain the machine during that year. Such contracts specify a time during which service can be obtained; a contract which includes the weekend and evening hours is more expensive. The service agreement may specify how rapidly service will reach you; such a feature is desirable.

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Political Considerations

The political considerations surrounding the use of a computer in educational applications should not be neglected. Before a computer facility can be acquired, it is generally necessary to have a group of personnel supporting and pushing for the acquisition.

Proposals that originate through faculty members, or faculty committees are more likely to result in viable educational computer programs than those coming from administrative sources. An interesting figure of merit is the cost per book checked out of the library versus the cost of processing a single computer program.

Consideration should be given to groups of colleges or universities cooperating in a consortium to operate a time-sharing computer. A valuable consulting service to colleges is available from the Association of Computing Machinery. Personnel from ACM can be made available to provide information and advice pertinent to the specific requirements of a college or university.

A final political comment is that it is often wiser to have seperate computing facilities for research, administration, and instruction, if possible. Seperate facilities guarentee the integrety of each requirement, and can possibly be cheaper than operating a large single facility to meet all three needs.